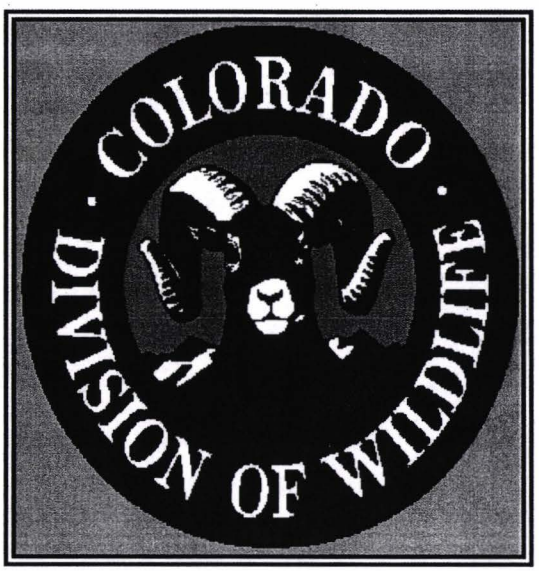
BASIN-WIDE STREAM HABITAT INVENTORY
A PROTOCOL FOR THE PIKE AND SAN ISABEL NATIONAL FORESTS AND CIMARRON AND COMANCHE NATIONAL GRASSLANDS

BASIN-WIDE

STREAM HABITAT INVENTORY

A PROTOCOL

(REVISED - APRIL 1997)



FOR THE

PIKE AND SAN ISABEL NATIONAL FORESTS

&

CIMARRON AND COMANCHE NATIONAL GRASSLANDS

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INTRODUCTION

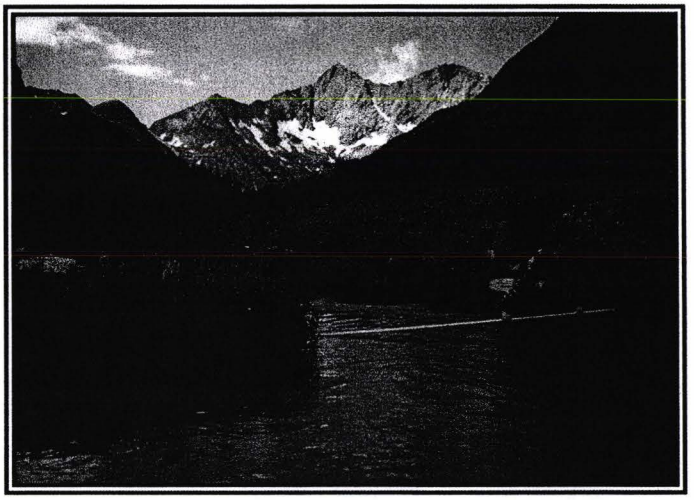
Management of the aquatic habitat encompassed by the Pike and San Isabel National Forests, Cimarron and Comanche National Grasslands is principally the responsibility of the USDA-Forest Service (USFS) and the Colorado Division of Wildlife (CDOW). These agencies are charged with the responsibility of managing a number of resources, in a manner which meets the goals and objectives of both Congressional and State legislatures, as well as our public. As part of the landscape based, ecosystem management approach adopted by the Forest Service, resource specialists from a variety of disciplines are typically involved in decision making activities. As a result of this integrated approach, quantitative inventories are an extremely important tool for future decisions affecting natural resources. Our methods for this inventory are based on many years of scientific research into the habitat requirements of fish, and also direction outlined by federal laws and regulations, including the Organic Administration Act of 1897, the National Environmental Policy Act of 1969, and the National Forest Management Act of 1976. We believe that an interdisciplinary approach to this aquatic inventory and monitoring program should compliment all resources of the Forest Service. These basin scale aquatic inventories can assist us in determining how to better manage all ecosystems (aquatic, riparian and upland) in a harmonious manner (Heede, 1984).

The Basin-Wide Stream Habitat Inventory was developed to provide a realistic and statistically valid overview of present stream conditions (Hankin & Reeves, 1988; Schmal et al., 1988). This technique has been shown to be more accurate than the representative reach approach, which had been historically used by the Forest Service for aquatic habitat inventories. Hankin and Reeves found that transects used in "representative reach", inventories tended to overestimate the amount of habitat available. The Basin-Wide Stream Habitat Inventory (BWSHI) approach developed by Hankin & Reeves requires the physical sampling of a specific set of habitat units within a given reach of stream. For example, beginning at the downstream boundary of a reach to be inventoried, the inventory crew would perhaps sample every seventh pool and every seventh riffle along the length of the stream until reaching the upstream boundary of the reach. Total habitat quantity, condition, and type can then be inferred using a statistical analysis of the data collected. The greatest benefit of this method is that a large portion of stream can be analyzed in a relatively short time, and for a comparatively small cost. Additionally, the method has been demonstrated to give a more realistic estimate of total available habitat within a given reach of stream compared to the representative reach/transect method of estimating aquatic habitat. Although BWSHI provides an excellent 'snap-shot' of current stream conditions, the most serious drawback to the Hankin & Reeves method of estimating habitat is that it is not repeatable, and therefore is not reliable for long-term monitoring of stream reaches (Azuma and Fuller, 1994).

The need for a protocol to quantify and monitor aquatic habitat conditions resulted in development of a modified version of the Hankin & Reeves methodology (Winters & Bennett, 1991). Our modified BWSHI methodology is intended to yield a repeatable mapping of the habitat available in a stream or drainage, by measuring a variety of habitat conditions in a given reach of stream. While somewhat more time-consuming and costly than the statistical method, we have found that the benefits of

inventory repeatability and use as a long-term monitoring tool make the slightly higher cost of this method worth the expense.

In the five field seasons that we have been performing aquatic inventories using this protocol, we have had ample opportunity to see what parts of the protocol were really effective, and what parts did not add value to the analysis. Each year, small changes have been made in several data collection methods, with some components being added and some being abandoned completely. The purpose of this revised edition of the Unit's BWSHI Protocol is to document these changes, and the rationale behind the modifications. The basic premise of the BWSHI, however, has remained the same, and this document draws heavily from the initial program of work.



The purpose of this inventory and future monitoring of priority streams, is to determine the limiting factors which affect fish quality, growth and reproduction within each stream in a watershed level approach. The technique of quantifying limiting factors, recognizes both beneficial and detrimental values. It is our opinion that by quantifying existing conditions, and by utilizing information developed in previous studies, we have selected those characters most readily apparent in limiting and impacting fish populations in the streams on our forests and grasslands. This methodology has been developed in a way that compliments other hydrologic and geomorphologic analyses, as well as terrestrial habitat inventories.

As a result of our observations, we have taken the basic Hankin & Reeves inventory plan and added several attributes which we consider to be significant limits to streams found on this Unit's forests and grasslands. Among these are a salmonid cover code classification and residual pool depth measurements which are critically important in providing security and overwinter protection of fish (Winters, 1990; Wesche, 1980; Lisle, 1987). We are also using a bank stability classification obtained from riparian studies in rangelands in Idaho (Burton, 1991). This stability classification is different from previous indices used in inventories (Pfankuch, 1975), because it is a non-rated protocol, which reduces the amount of personal bias.

METHODS

The methodology involved in this inventory is a compilation of previous studies and should not be misconstrued to be an original program of investigation. It is intended to provide management with the proper analysis on which to base future decisions affecting the Pike and San Isabel National Forests and the Cimarron and Comanche National Grasslands.

OFFICE PROCEDURES

Prior to the field inventory, an in-house assessment is made on each stream and each reach to be inventoried. At this time, streams are prioritized for inventory, stream reaches identified, and reach boundaries are determined. Reaches should be numbered consecutively, beginning at the confluence of the stream with another stream or river. Delineation of reach boundaries is critical to maintaining repeatability of the inventory for monitoring purposes. We generally recommend that reach boundaries be placed at easily identifiable locations, such as tributary confluences or permanent structures such as highway bridges. Sometimes, stream geomorphology and channel geometry, or private property issues may preclude using the above methods. In this case, it is absolutely necessary to locate the beginning of the reach with a GPS unit or some other repeatable method in the field. Additional information regarding historic use and condition may also be collected at this time in order to provide pre-inventory documentation on each reach in the stream, and also a summary of some field information.

The General Reach Habitat Pre-Inventory Form (Appendix I) may be used to summarize all pre-inventory information and documentation collected from USGS topographical maps (1:24,000 scale), aerial photographs, and other available sources of data relating to the stream. The pre-inventory collection analysis is useful to uncover any previous data collected (i.e. Level 1 Watershed Assessment analysis, water quality, creel census, earlier habitat studies, recreation, road maintenance, or other management activities) to allow for specific and correct collection of data of the stream under study. The documentation includes:

Upstream or downstream: These blocks are used to indicate the direction the inventory team accomplished the study. This is included to avoid confusion in the analysis portion of the study in the office.

Date(s): These are the actual date(s) in which the specific field inventory is accomplished.

1. Stream Name: The name of the stream as it appears on the USGS map.

2. State: 08 is the code for Colorado.

3. Forest: Use code 12 for the Pike and San Isabel National Forests, use CR for Cimarron National Grassland, and CM for Comanche National Grassland.

4. District:
   LD - Leadville SA - Salida SC - San Carlos
   CO - Comanche CI - Cimarron PP - Pikes Peak
   Spk - South Park SPl - South Platte.

5. USGS Map — The name of the USGS map containing the reach.

6. Catalog No. — Refer to Forest Service Handbook 2609.23 Fisheries Habitat Surveys Handbook (3.11c-14-18).

7. Reach Legal Location — Record the Township, Range and Section of the downstream end of the reach. Delineate the section down to 40 acres for closest proximity to the downstream end of reach. Additionally GPS location, in either Latitude/Longitude or Universal Transverse Mercador (UTM) can be entered here.

8. Reach No. __ of __ — List the number of the reach being inventoried in the stream and its placement to the number of other reaches which will be inventoried.

9. Reach Elevation and Aspect — List both the upper and the lower reach elevations and the general aspect of the watershed.

10. Reach Gradient — The gradient is the general slope or rate of change in vertical elevation per unit of horizontal distance of water surface of the stream. Determine the gradient as a percent, by dividing the difference in elevation between the upper and lower end of the reach, by the total length of stream in the reach. Stream gradient can also be measured in the field, so a comparison can then be made with the gradient as it was determined in the office. The most accurate method in the field to calculate slope is to perform a vertical survey using an auto-level and tripod, stadia rod and steel measuring tape, however this is not always a viable option due to time and equipment constraints. An alternative method, if collecting GPS data on the reach, is to use the altitudes determined at the upstream and downstream boundary features, and the length of the stream reach as determined in the inventory. Additionally, the gradient may estimated by measuring the angle from the horizontal on two selected points at mid-stream with a clinometer or Abney level. However, it should be noted that this method provides very course estimate of gradient, and is subject to significant error.

11. Photograph Exposure — This is a record of the roll of film used and the individual photos that were taken on the reach. On the field data form, record the photo # taken in the comments section and give a brief description.

12. Dominant Riparian Vegetation — From observations made in the comments section of the field form, record the species of riparian vegetation observed along the reach.

13. Riparian Zone Width — Record this width, to the nearest 1 foot. The average width of the area in which riparian vegetation is growing in the reach. Riparian mapping has been accomplished on the forest and these maps, if available can be useful for determining the width and type of riparian zone the stream occupies.

14. Valley Bottom Width — Record this width, to the nearest 10 feet. The average width of the valley floor, which is an average of the distances at each end of the reach and the midpoint.

15. Valley Bottom Shape — Record the appropriate code describing the valley shape:

1. U-shaped; 2. V-shaped; 3. Broad

For a more detailed evaluation of valley bottom classification refer to USDA, FSH 2609.3, Exhibit 3-25 (3.3 lf-19).

16. Discharge — Record the measured discharge in the reach in cubic feet/second and record the data and calculated results in Appendix V.

17. Mean Velocity — Determine the mean velocity in ft/sec while determining the discharge, record in Appendix V.

18. Current Meter — List the type of current meter used to measure the discharge and velocity. If dye is used then record the amount of dye and the time to delivery.

19. Channel Type — From aerial photographs and/or field observations, identify the type of channel and subtype for the stream, using Rosgen's classification scheme (1985). Visually classify the channel subtype in the field.

20. Fish Species Densities — Record the fish species present in the reach. Consult CDOW agency records for this information, especially if the reach has recently been sampled.

21. Bank Full Width and Depth — Measure the bank full width and depth to the nearest tenth of a foot and

22. Comments — Include any important aspects or concerns about the reach, areas of the reaches which require particular attention, or any other details not covered above.

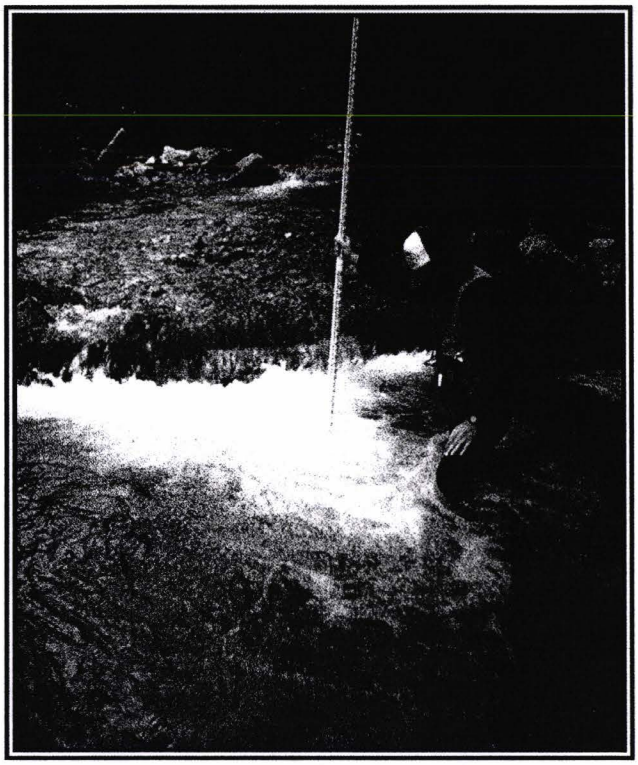
23. Investigators — Record the names of the individuals involved in the inventory on the reach.

FIELD PROCEDURES

In order to quantify the attributes we have selected for measurement in the field inventory, a concise field form was developed (Appendix II). This form was developed, in order to make field collection as efficient as possible. The measurements collected on this form are based on the goals and objectives of the particular inventory and/or monitoring study. The field form contains protocols for the maximum amount of information needed for our BWSHI. However, the form contains only a portion of the data requirements which may be needed in other studies.

Upon reaching the field, crews should accomplish several items prior to taking measurements. The stream name, reach number, and all the information needed at the top of the field form should be filled-in. This may seem trivial, however, when several reaches and streams are inventoried in a short time period, this information could be lost. A Max-Min thermometer should be placed in the stream, prior to the inventory. The time should be recorded when the thermometer is placed into and also when removed from the stream. The temperature readings should be recorded immediately upon removal of the min-max thermometer from the stream . This method of measuring temperature should not be construed as a quantitative analysis of long-term trends. However, it does give an indication of current conditions.

Stream discharge should be measured before conducting the habitat inventory in order to confirm that flows are at or near mean low flow levels for the reach being studied. It is critical that all aquatic habitat inventories be conducted using consistent flow regimes, in order to allow for comparative analysis across similar drainages. Under our protocol, we have selected mean low flow discharge for inventory analysis. We believe that under these reduced flows, we can more accurately identify and model the limiting factors affecting fish populations in the streams found on our forests and grasslands.



If a global positioning system (GPS) is going to be used to identify stream reach boundaries, the upstream and downstream reach boundary point features should be collected at this time, using a minimum of 180 data points collected for each boundary point feature. Additionally, a GPS line feature should be collected of the stream channel throughout the reach, if the inventory data is going to be used in any spatial or Geographic Information System (GIS) analysis. A GPS line feature will allow you to use the dynamic segmentation utility available in many GIS packages to spatially link the length field in your BWSHI database. The potential applications that can be developed using this spatially linked data can easily justify the additional time spent in collecting the GPS line feature. After collecting GPS data, it is critical to record the GPS file name in the header section of the field form.

The channel subtype classification, the riparian zone width, as well as the valley bottom width and shape should be measured and recorded. Some time should be spent classifying the dominant riparian vegetation. Z-Walk pebble counts can be measured at anytime on each reach. In the field, each reach along the stream will be measured and visually described using the protocol described in Habitat Type Classification and Definitions. A 'help sheet' of the items required to be measured in the inventory should be a part of the field equipment, and is provided to make the measurements more

precise, and to avoid confusion (Appendix III). We have found it useful to laminate this 'help sheet' to the backside of the data recorder's clipboard. The Z-Walk Pebble Count Data form and Stream Discharge Form are also included in Appendix II, and can be copied or printed onto the reverse side of the Habitat Inventory Form, making storage of field data more efficient. These field forms should be copied or printed on 'Rite in the Rain' paper to insure the field inventory data is retrievable upon return to the office. Programs for the calculation of discharge and pebble count evaluations are currently available on our PC compatible computers. Although these relatively simple calculations could be programmed into the DataGeneral system, the main Basin-Wide Stream Habitat Inventory analysis is probably too large to be programmed efficiently in this system. For this reason, we have developed a PC based Database and Analysis package for use with this protocol (Gallagher and Winters, 1994).

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HABITAT TYPE CLASSIFICATION AND DEFINITIONS

Fish habitat in streams has traditionally been classified into a variety of zones based on channel characteristics (Platts, 1974), associated biota (Huet, 1959), or a combination of physical, chemical and biological features (Binns and Eiserman, 1979). We have chosen to classify fish habitat types as described by Bisson and others (1981) for small streams. These habitat types are classified, based on their location within the channel, pattern of water flow, and the nature of flow controlling structures (Bisson, 1981). The terms "riffle" and "pool", are the basic units of channel morphology, yet they convey many different images to different persons. By standardizing and defining in detail, these ambiguities will hopefully be resolved. The discussion which follows will help to define the terminology used in this inventory. The explanations for each habitat unit type will also include a general discussion on why each habitat unit type is important to fish.

HABITAT UNIT TYPES (HUTS)

We have delineated areas within a stream into three major Habitat Unit Types (HUTs), and these are, glides, pools and riffles (Bisson et al, 1981). Pools are further classified into six sub-categories: side channel, backwater, trench, plunge, lateral scour and dammed pools. Riffles are further classified into five sub-categories: secondary channel riffles, high gradient riffles with substrates of bedrock and boulder, low gradient riffles with substrates of cobble, gravel or sand/silt, rapids and cascades. Glides are not sub-classified. The explanations provided below are revised from the Pacific Southwest Region Habitat Typing Field Guide (USDA-USFS). Each HUT is further broken down into its consecutive order (numerical), type, and structural association.

GLIDES

Glides are those portions of streams which have relatively wide uniform bottoms, low to moderate velocity flows, lack pronounced turbulence, and have substrates usually consisting of either cobble, gravel or sand (Diagram 1 & Photo 1). Glides are usually described as stream habitat, with characteristics intermediate between those of pools and riffles. These habitats are most often found in the transition between a pool and the head of a riffle, however they are occasionally found in low gradient stream reaches with stable banks and no major flow obstructions (Bisson et al., 1988) Due to the predominance of headwater tributaries with moderately high gradients found on this Unit, this form of habitat is the least expected and measured in streams on our forests. Glides are labeled in this

Diagram 1: Structure of a typical glide habitat.

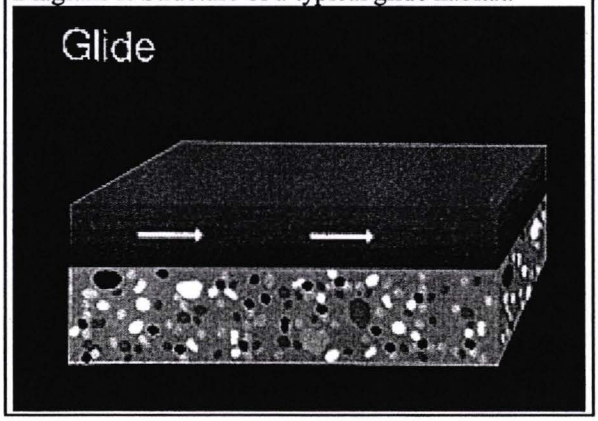


Photo 1: Glide habitat on Wigwam Creek

protocol as a number G1...G[n], and further structural classification is not delineated.

POOLS

Pools are those units which usually maintain water levels even under dry or intermittent conditions of water flow. Pools are extremely important for trout survival, and in many cases (especially in 3rd order or smaller streams) may limit population size and growth. However, it should be noted that the lack of pools may be the a result of other factors in the drainage that are limiting their formation or stability. The sub-categories described below are the types of pools which may be found in low streamflow conditions (Bisson et al., 1988). Pools are numbered as P1...P[n], and are typed as follows:

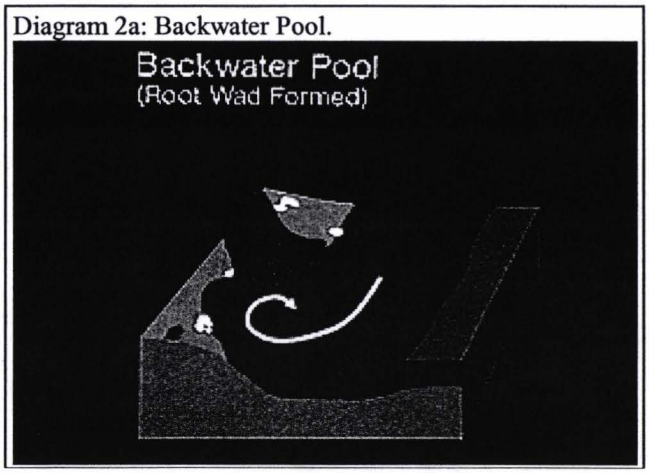
Secondary channel pools

Secondary channel pools are those pools found outside of the main wetted channel width. During summer, these pools may dry up or have little to no flow into them. These channel pools are usually associated with mid-channel bars, and may contain deposits of sand and silt. The current velocities in these pools are usually very low, compared with the main stream channel velocities. Due to the low velocities, these pools may be very important in providing rearing habitat for juvenile and young-of-the-year fish.

Backwater pools

Backwater pools are found along channel margins and are formed by eddies around obstructions such as boulders, rootwads, or woody debris (Diagram 2a). These pools may be shallow or deep, and are typically dominated by fine-grain substrates. Current velocities are usually low in these pools, and they may be important in providing rearing habitat for juvenile fish,

Diagram 2a: Backwater Pool.



Trench pools

Trench pools, often called chutes (Diagram 2b and Photo 2), are those pools in which the cross-section of the water column is typically U-shaped with bedrock or coarse grained bottoms flanked by boulder or bedrock walls. Current velocities in trench pools are typically the highest of any pool type and the direction of flow is generally uniform.

Diagram 2b: Structure of a trench (mid channel)Pool

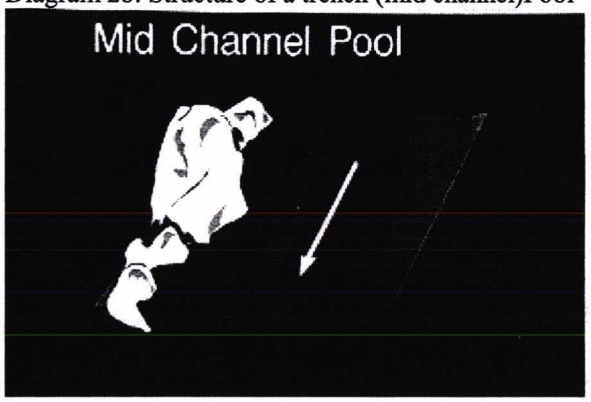
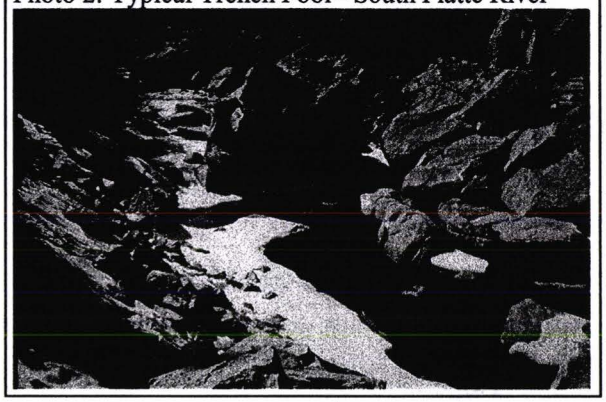


Photo 2: Typical Trench Pool - South Platte River



Plunge pools

Plunge pools are created when the stream passes over a complete or nearly complete channel obstruction and drops steeply into the streambed below, scouring the downstream substrate, and forming a depression (Diag. 3 & Photo 3). Water velocities and energy are greatly reduced in these types of pools. These pools may often be large and deep, and their substrate size is highly variable. In disturbed streams, these pools may be significantly impacted due to deposition of sediment and subsequent reduction in depth. In higher gradient headwater tributaries, these habitats are where adult fish are often found, primarily due to the reduced velocities, increased depths and availability of cover. They are often the only habitat available in smaller streams for both adult and juvenile fish to overwinter. Thus these pools are very important habitats in mountain streams.

Lateral scour pools

Diagram 3: Structure of a Plunge Pool

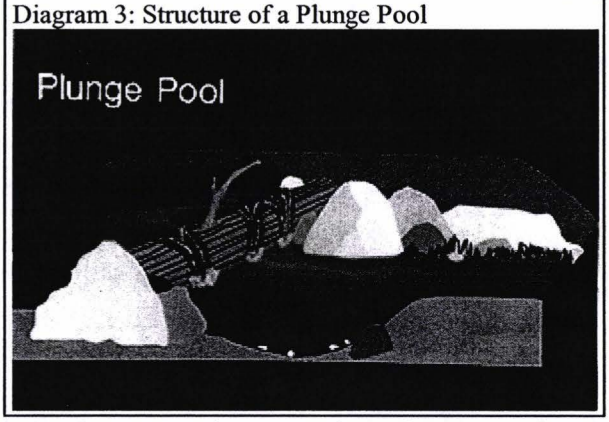
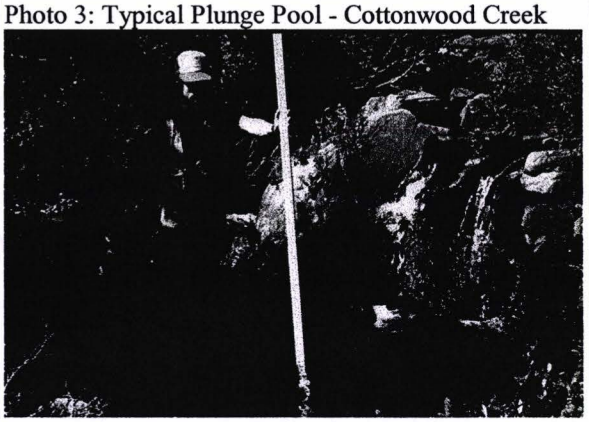


Photo 3: Typical Plunge Pool - Cottonwood Creek



Lateral scour pools occur where the stream flow impinges against one streambank or against a partial channel obstruction (Diag.4 & Photo 4). The associated scour is generally confined to <60% of the wetted channel width (McCain, et al, 1990), and obstructions which may be associated with these pools are rootwads, woody debris, boulders and bedrock. Lateral scour pools generally occur in low gradient, meandering streams. Sediment deposition in this habitat type is quite distinct, characterized by bars forming on the inside of the meander bend. These pools often contain adult fish which utilize the overhanging and undercut outer banks of the meander for cover and feeding. The macroinvertebrate drift entering these pools from riffles at the point of entrance make these prime habitats for feeding trout.

Diagram 4: Structure of a Lateral Scour Pool

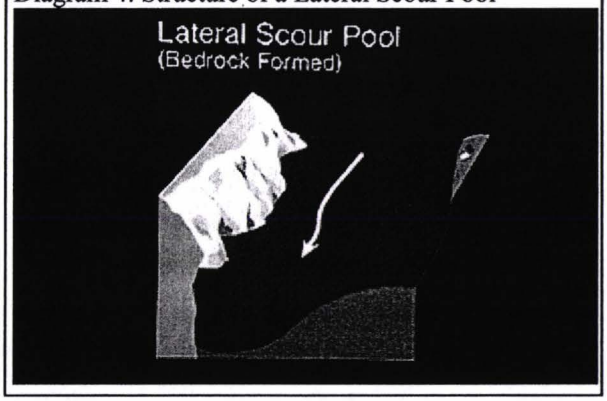
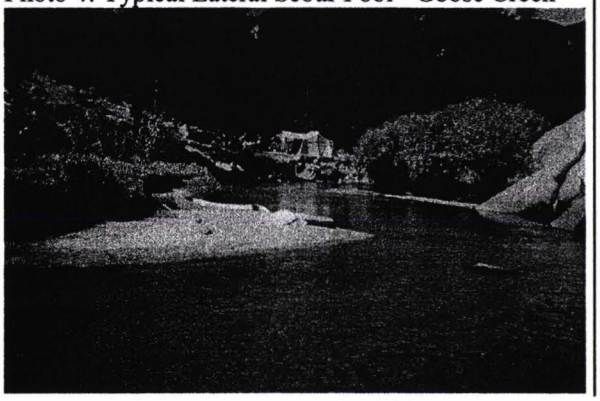


Photo 4: Typical Lateral Scour Pool - Goose Creek



Dammed pools

Dammed pools are those habitats which are formed by impoundment of the stream flow resulting in complete or nearly complete channel blockage (Diag. 5 & Photo 5). The dams may be the product of debris jams, rock landslides, beaver dams, or man-made structures. The substrates associated with these pools tend toward smaller gravel and sand. Adult and juvenile fish will be found in these pools, which may provide cover, and shelter from excessive velocities. However, these types of pools trap sediment moving down the stream channel. As a result, dammed pools usually provide adequate cover for only a short period of time, eventually filling and becoming more characteristic of a glide or shallow riffle.

Diagram 5: Structure of a Dam or Debris Pool

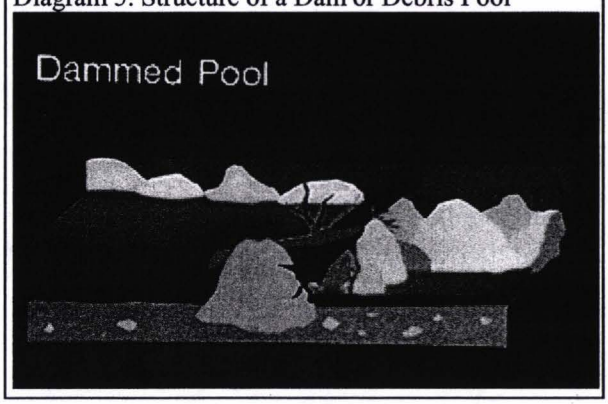
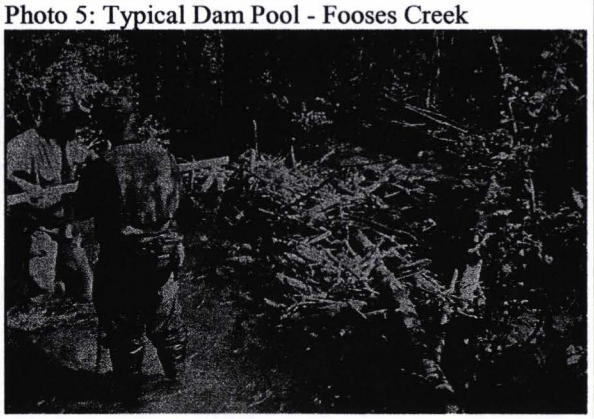


Photo 5: Typical Dam Pool - Fooses Creek



RIFFLES

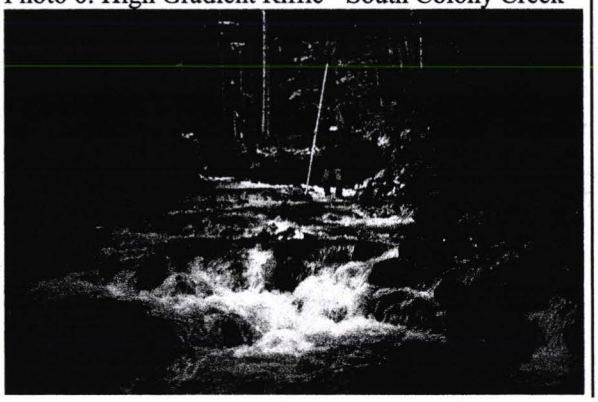
Riffles are those areas of the stream in which turbulence in the water column is the major identifying characteristic, as a result of relatively high gradients. These units contain moderately deep to shallow, swift flowing water, and are characterized by boulder or cobble substrates. Riffles are numbered as R1..R[n] on the field forms, and are differentiated by being either secondary channels, or by their difference in substrate composition (bedrock, boulder, cobble, gravel, sands and silts). Riffles are very important for macroinvertebrate production, due to the availability of light and oxygen, and the corresponding vegetative growth on the bottom substrate. The quality of riffles, including low sediment deposition and resulting embeddedness can have a direct impact on fish populations. The cleaner and healthier the vegetative growth and benthic macroinvertebrate community, the more food there is for the fish population.

High gradient riffles

High gradient riffles (Diagram 6 & Photo 6) are those riffles which have gradients greater than 4%. These riffles are found in moderately deep, swift flowing water, and are typically associated with either bedrock (parent rock material) or boulders, though large cobble substrates may occasionally be found in these riffles.

Diagram 6: Structure of a High Gradient Riffle

Photo 6: High Gradient Riffle - South Colony Creek



Low gradient riffles

Low gradient riffles (Diagram 7 & Photo 7) are those riffles which have gradients less than 4%. These riffles are associated with shallow but swiftly flowing water and normally have cobble, gravel, or sand/silt substrates.

Diagram 7: Structure of a Low Gradient Riffle

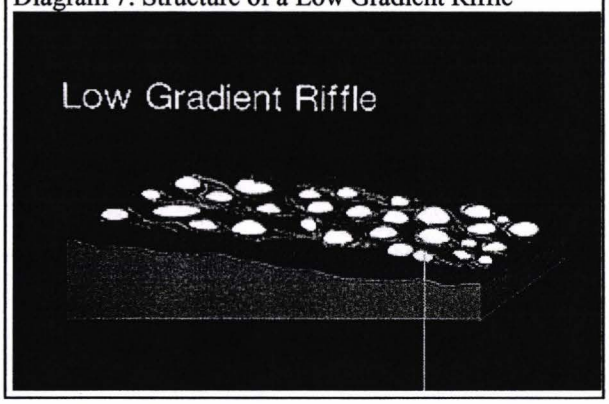


Photo 7: Low Gradient Riffle - Clear Creek

Rapids

Rapids are riffles associated with high gradients (greater than 4%) with swiftly flowing (greater than 1.5 ft/sec), moderately deep, and highly turbulent waters. These riffles are generally associated with boulder substrates, which protrude through the surface of the water.

Cascades

Diagram 8: Structure of a Boulder Cascade

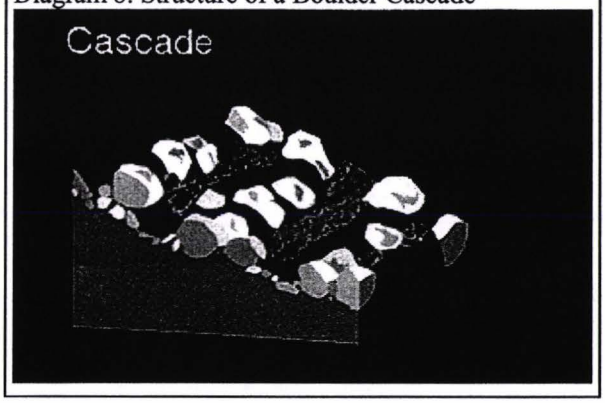
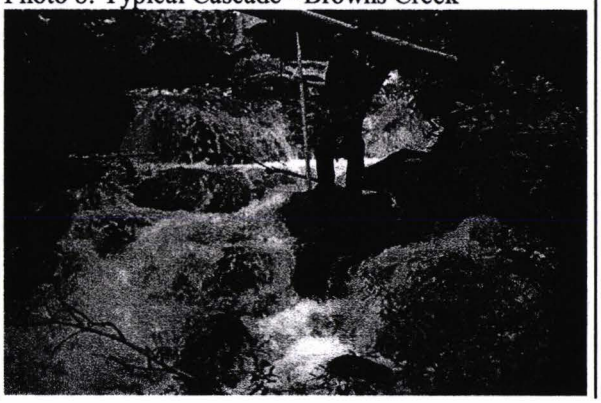


Photo 8: Typical Cascade - Browns Creek



Cascades are the steepest riffle habitat unit types, in terms of gradient, in streams. These riffles consist of alternating small waterfalls and shallow pools (Diagram 8 & Photo 8). These habitats may appear to have the characteristics of a Step-pool system, but in our classification system are not recorded as such due to the pools being typically smaller than the width of the channel. Potential habitat for fish in this riffle type is best quantified by calculating the available cover in these small pocket pools, rather than measuring each pocket water as a separate pool. Cascades are characterized by swift current flows and often have exposed rocks and boulders above the water surface, which creates considerable turbulence and surface agitation. The substrate normally found in cascades is bedrock or accumulations of boulders.

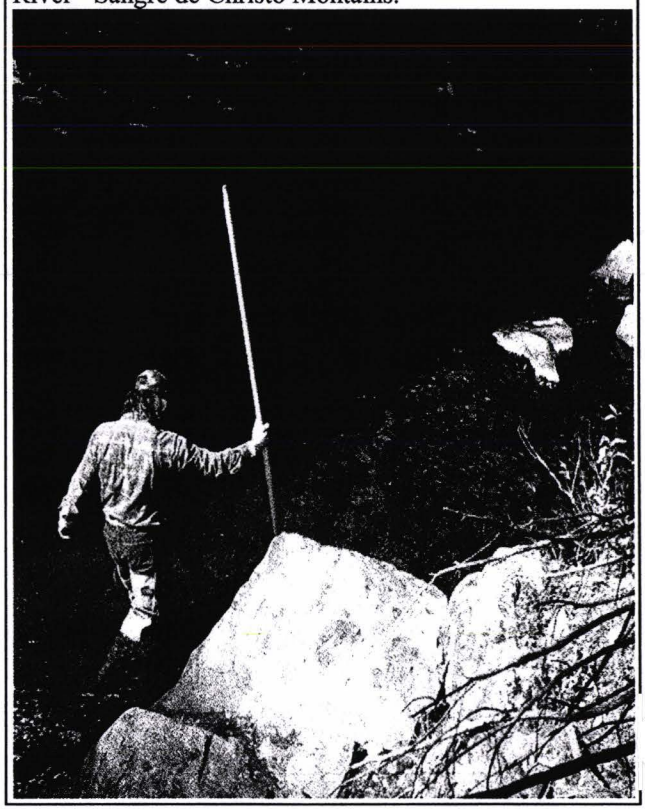
STRUCTURAL ASSOCIATION

Structural Association (SA) is used in this inventory to describe the structure identified with a given habitat unit type. Glides are not identified with any structural associations, because they are considered intermediate between pools and riffle habitats. *Pocket water* and *Other* are the two structural components associated with riffles. *Other* is considered as cobble, gravel, sand/silt/mud substrates, plant material in the stream bottom, and is only applicable to low gradient flow riffles. All of the remaining structures used in this inventory are associated with pool habitat types. The following are the structural associations used in this protocol:

A -point or mid-channel bar B-boulder C-culvert D-beaver dam E-bedrock F-falls L-LOD M-meander O-other P-pocket water R-rootwad S-structure W-debris dam/large wood

Structural association is defined as the predominant feature that forms the habitat unit being observed. Occasionally, there may be several physical features that appear to be creating the habitat, and it may be difficult or impossible to determine the primary structural association in this case. An example of this difficulty is a trench pool where the flow of the stream is being concentrated by different physical features, such as a root-wad and a boulder, on either side of the channel (Photo 9). In this case, we will attempt to determine a primary and secondary structural association for the habitat unit, entering first the primary then secondary value in the SA column on the field data form separated by an "/". It is a good idea to document these habitats with a photograph or comment in the comment column of the form in order to justify the reasoning for assigning one structural association dominate over the other.

Photo 9: Example of a HUT exhibiting more than one structural association. Note the bedrock structure on the left bank and the boulder and rootwads on the right. These two structures are forcing the current to scour a mid-channel trench pool in this habitat. Upper Huerfano River - Sangre de Christo Montains.



SURFACE AREA / VOLUME MEASUREMENTS

AVERAGE LENGTH

The length of each HUT is measured in feet (to the nearest 0.5 ft), using either a 100 foot measuring tape or a calibrated rangefinder. The determination of the end point of a given HUT is dependent on the inventory team, using a consistent approach. Often HUT's will be easily distinguished from each other (smooth water in glides versus rough water in riffles). However, there can be a large amount of variance between end points and start points of other HUT's. When no clear distinction is available, the team must average the differences or overlaps of the two HUT's and use this same consistent approach in all future cases. Hankin and Reeves (1988) used this premise of consistency when discussing irregular ends of pools. They adopted a rule that the 'end' of the pool is the midpoint between the point at which the pool becomes irregular in shape and the irregular endpoint of the pool. We use this same reasoning in our length measurements. Positions of measurement for HUTs beyond 100 feet can be delineated by the investigating team by placement of a marker (a piece of fluorescent tape or some other noticeable object) to reduce the measurement error as the team moves upstream along the HUT.

AVERAGE WIDTH

Width is described as the wetted cross-section of the stream channel, and is measured at a minimum of three different points along the habitat unit, and the average width is calculated. In the case of very long HUTs, width measurements are taken at intervals of 10% (i.e. if the HUT is 500 ft in length, width measurements would be taken every 50 feet, thereby obtaining average measurements of width along 10% of the HUT). A significant amount of bias can be introduced to the data in this step. Field experience has demonstrated that many individuals, particularly those new to this inventory protocol, tend to take width measurements only at the widest or narrowest parts of the channel within a given habitat unit. We cannot stress enough the importance of random sampling in this measurement. Typically, in a small habitat, we divide the length of the habitat in thirds, and take a width measurement at these points. On longer habitats, we use the specified interval method described above.

RESIDUAL POOL DEPTH

Residual Pool Depth (RPD) is estimated as the depth of water which would be retained in a pool under highly reduced flows or the stoppage of flows in the stream. This area of pools would be utilized by fish in low flow conditions. Residual pools would also provide habitat for overwintering of fish when ice buildup restricts movement in riffles or glides between pools. Residual pool depth is calculated by locating and measuring the greatest depth of the pool at the riffle crest (deepest point of the downstream boundary cross-section of the pool), and subtracting this value from the greatest measured depth of the pool habitat. The difference in these measurements is described as the RPD (Lisle, 1987). RPD may be difficult to determine in some habitats, particularly dam pools with woody debris structural associations. In many of these habitat units, the RPD may actually be a very low value or zero due to water flowing through these debris dams.

MAXIMUM DEPTH

When maximum depth is located and measured for Residual Pool Depth Calculation, it should also be recorded on the Inventory Form in the Max Depth column. We have been recording this information as part of our efforts to streamline and combine various hydrological and aquatic protocols such as the USDA Forest Service Region 2 T-Walk stream health survey(Ohlander, 1996) and BWSHI.

AVERAGE DEPTH

Depth measurements are taken only within pool habitats, and are taken at intervals of at least three measurements across the width of the unit. A minimum of nine depth measurements should be made within any habitat unit. Intervals of depth measurement coincide with the number of width measurements taken on the habitat unit, and are typically made along the width measurement cross-section in order to force a random sampling of depth. In order to prevent the introduction of personal bias in this measurement, we typically will divide each width cross-section into three of four equal intervals and take depth measurements at these points. Each depth measurement is then averaged to provide the mean depth of the habitat unit being studied. In the case of large dam pools and beaver ponds more than three of four depth measurements may be required. In these cases, depth measurements at intervals of 10% to 20% of the habitat width may be required. In extreme cases, these habitats may be so deep that depth measurements may be impossible without some form of

floatation device. In these cases, we typically will make an ocular estimate of the average depth of the habitat unit to the nearest foot.

COVER TYPES

Locations where fish prefer to rest, hide and feed are called cover. Cover serves to visually isolate fish, which increases the number of territories in the same space (Hamilton & Bergersen, 1984). Additionally, cover can create areas of reduced velocities providing critical resting and feeding stations for fish (Schlosser, 1982). The amount of cover available in a stream can influence the production of a number of fish and invertebrate species. Cover can be a feature of the aquatic environment which is difficult to quantify, and it's evaluation may be subjective. However, by following a given protocol and having prior knowledge of species preferences in the streams being inventoried, quantification of the amount cover available is possible. Numerous studies have included a rating factor to reflect these species preferences (Wesch, 1980) but we do not use a rating in our analysis. Salmonid cover types are modified from Bovee (1982) and Marcus and others (1990), and are specifically coded and explained in Winters (1990). These variables estimate the amount of cover available to both adult and juvenile salmonids within the stream conditions found on the forest. The quantity of suitable cover has typically been found to be the single greatest limiting factor to successful fish propagation on the small headwater streams found on this Unit's mountain districts. Additionally, available suitable cover may be significantly impacted by existing and proposed land management practices and disturbances within the aquatic ecosystem. The categories of cover used in this inventory are described below:

1. NO COVER

No Cover is defined as the lack of holding, escape or other cover forms in HUTs. Trout will generally avoid these areas due to inadequate water depths (<0.5 ft) in combination with excessive velocities, (~0.5 ft/sec) in riffles; and the absence of security cover or a combination of factors in pool habitats (i.e. <1.5 ft in depth, and provides no security cover for fish).

2. INSTREAM COVER

Instream Cover is defined as obstructions in the channel which provide shelter from excessive current velocities (Photo 10). These areas provide microhabitats for resting as well as feeding stations for trout during most of the year. Instream objects are defined as channel obstructions which offer a minimum of 1 foot in width (measured perpendicular to the current) and have a minimum depth of 1 foot of water behind a 1 square foot sized object. Objects considered as instream cover include: large organic debris (LOD), which is material such as tree trunks or rootwads, and boulders which are located in the stream channel. These objects provide areas of reduced velocities but offer no security cover. While objects smaller than described may be utilized, these criteria for instream cover are applicable particularly during snowmelt runoff when velocities are greatest and the cover produced behind these kinds of objects results in a velocity less than 0.5 cfs.

3. OVERHEAD COVER

Overhead cover is used primarily for resting or feeding fish. Trout utilize these objects to avoid predators and the affects of direct sunlight. Normally, overhanging vegetation provides shading of the stream. Overhead cover, as used in this protocol, are objects within 2 feet of the water surface, which

provide a minimum of 1 sq. ft of cover over water having a minimum depth of 0.5 ft.(Photo 11). Overhead cover provides no velocity shelter to fish and again is considered relevant only when flow rates are < 0.5 cfs. In conditions where excessive flow velocities are prevalent, surface turbulence could provide some form of this of cover. However, as used in this protocol, we associate surface turbulence with other forms of cover, such as instream object cover (code 2) and pool depth (code 5).

4. COMBINATION COVER

Combination cover provides both a velocity shelter and overhead cover to fish. In this category, the water level must be a minimum of 0.5 ft deep, and may consist of fallen trees, debris piles with branches, and/or root masses, overhanging or undercut banks with roots, rubble or boulder piles within the stream channel (Photo 12). The key to this type of shelter is that it provides both overhead security while sufficiently reducing instream velocities.

5. POOL DEPTH COVER

Pool depth is an important form of cover for fish and it is used for escape and as security cover from predators. Pool depth is also important in providing security from excessive velocities and offering visual cover. In areas where encroachment of shelf and anchor ice occur, this form of cover will provide habitat to trout for surviving and overwintering during critical environmental extremes (Platts, 1983). Pool depth is that amount of cover, which has a minimum depth of 1.5 ft.(Photo 13). Cover codes 2, 3 & 4 above should be measured and recorded initially and the remainder of the area greater than 1.5 feet deep then qualifies as pool cover.

Photo 10: Instream Cover - Area Behind Boulder

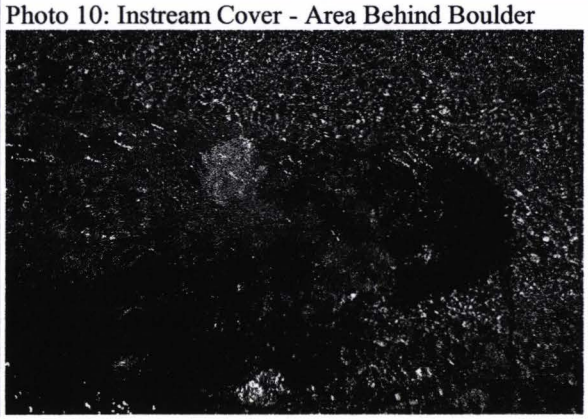
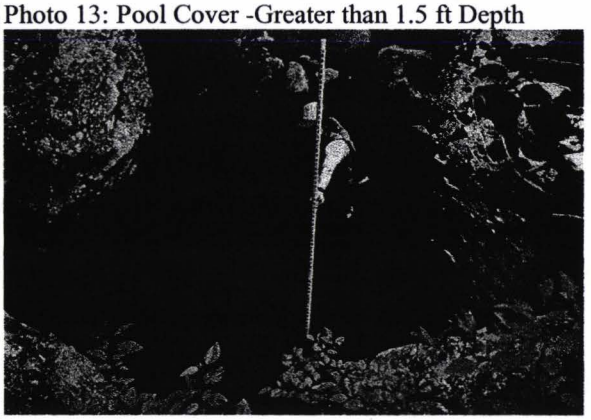


Photo 11: Overhead Cover - Underneth Willows

Photo 12: Combination Cover - Undercut Bank

Photo 13: Pool Cover -Greater than 1.5 ft Depth



Measurement of cover types along very long habitat units such as riffles is facilitated by using the column grid located on the upper right area of the Inventory Field Form (Diag. 9). Individual cover type measurements, as well as linear feet of eroding banks or other variables, can be penciled into the appropriate columns located on this portion of the form, then totaled and entered into the appropriate field columns of the habitat unit record when the end of the unit is reached. The data recorder can then erase the individual measurements from these temporary columns and begin anew at the next long habitat unit.

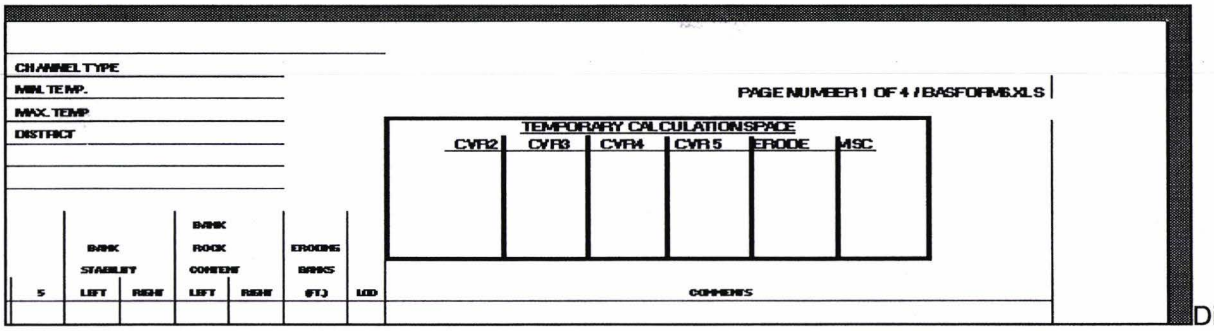


Diagram. 9. Temporary cover, eroding bank, and misc. data grid on field form for keeping track of multiple cover and other measurement variables on very long habitat units.

BANK STABILITY

Bank Stability is used in this inventory to describe the vegetated state and the stability of the stream banks (Burton, 1991)(Steve Kozel, USFS 1991, pers. comm). The conditions of stream banks are a very good indicator of possible impacts in the watershed. Deposition of sediment from upstream activities can result in unstable bank conditions, as can activities along the adjacent stream banks themselves (e.g. mass waste slopes). Cattle grazing, adjacent road activities and catastrophic events (e.g. high spring runoff and flash flooding) appear to be the most common factors which cause of bank instability in the streams we have observed. To determine the stability of each bank, we observe each bank independent of the other and utilize the coding system described as follows:

Code ***1***. The bank is greater than 50% vegetated and shows no sign of stress (photo 14).

Code ***2***. The bank is greater than 50% vegetated but shows stress or degrading and eroding banks (Photo 15)

Photo 14: Bank Stability Type 1. Poncha Creek

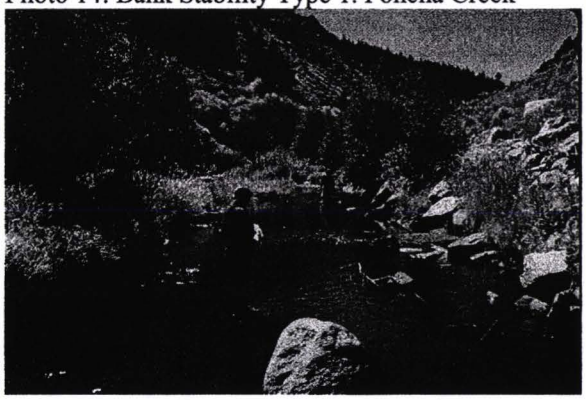


Photo 15: Bank Stability Type 2. Wigwam Creek

Code ***3***. The bank is less than 50% vegetated, and the bank itself is stable showing no erosion or degradation of the bank (Photo 16).

Code ***4***. The bank is less than 50% vegetated, and shows stress associated with eroding or degrading banks (Photo 17).

BANK ROCK CONTENT

Bank rock content is taken from the Channel Stability Evaluation (USDA-FS, 1975) and the criteria is:

1. A rating of ***2*** is given if the bank rock content is greater than 65% of large and angular boulders which are 12 inches greater in diameter,
2. A rating of ***4*** is given if the bank rock content is between 40-65% of mostly small boulders to cobbles in the range of 6-12 inches in diameter,
3. A rating of ***6*** is given if the bank rock content is between 20-40% of mostly rocks in the 3-6 inch diameter class,
4. A rating of ***8*** is given if the bank rock content is less than 20% of rock fragments of gravel size, 1/8 - 3 inches in diameter.

Photo 16: Bank Stability Type 3. South Platte River

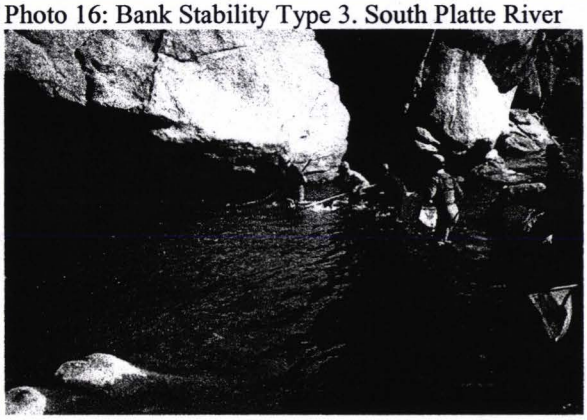
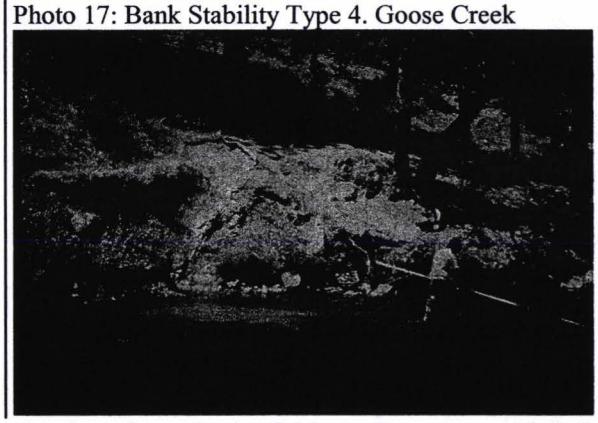


Photo 17: Bank Stability Type 4. Goose Creek



These values are a general criteria for the size of the bank rock content. Odd number values of ***3***, ***5***, and ***7*** may be assigned to each bank if the average size of bank rock falls between these parameters.

LARGE ORGANIC DEBRIS - LOD

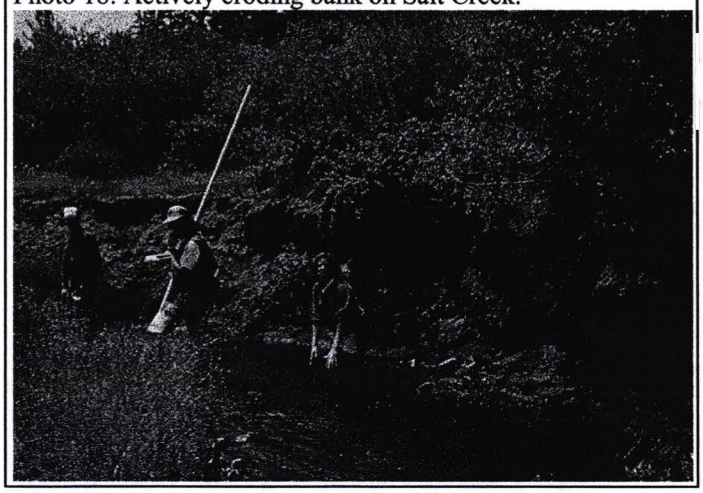
Large organic or woody debris influences a number of important factors in the stream system (Gibbons et al., 1990). Indeed, in the Pacific Northwest, large wood is considered the principle critical habitat

forming feature, and in many basin inventories performed in that region, large wood is the only stream attribute quantified. Large pieces of wood and fallen trees which are found in the stream can significantly shape the stream channel, provide an energy base (nutrients) to the stream, and influence the composition of fish species and the quantity of fish. The primary effects of logs or trees on stream channels are related to changes in streamflow patterns. Pools are formed by the stream scouring around and under logs. Gravel and sediment are stored behind these objects and undercut banks can be created by water being deflected against a stable bank. All of the attributes contribute to a variety of habitat types that can be used by trout and the organisms they feed on. Definitions of large organic debris (LOD) vary widely throughout different regions. In small mountain tributaries with relatively limited flows, even small branches and logs may be significant structures within the stream. On the opposite end of the spectrum are the large streams and rivers of the Pacific Northwest, where any wood less than three feet in diameter is considered to be transitory in nature and is not measured as LOD. We define LOD, for the purposes of this inventory, as the amount of relatively stable woody material found in the stream. This debris must have a diameter greater than 4 inches and a length greater than 3 feet. LOD is recorded as the total number of objects (fitting the dimensions), found totally or partially within the stream channel (Helm et al., 1983).

ERODING BANKS

This attribute is used in this inventory to describe those areas which are showing active erosion. Banks which show slumping into the channel, are steep in gradient and consist of unconsolidated soils and those where excessive use caused by trampling and denuding of vegetation by either livestock/wildlife or man are considered eroding banks (Photo 18). A good general rule of thumb when quantifying these banks is whether material would erode into the stream from these areas in a moderately heavy rain, such as is typical of an afternoon thunderstorm in the Rocky Mountains. These banks are measured in terms of the amount of bank eroding, in linear feet. Each bank is measured separately and the sum of both banks is used as the total of eroding stream bank, in each habitat unit (Binns, 1982).

Photo 18: Actively eroding bank on Salt Creek.



SUBSTRATE COMPOSITION

Originally, substrate composition in this protocol was assessed by visual approximation. The percentage of the substrate material on which the stream flows was estimated to the nearest 5%. No attempt to assess the amount of embeddedness of the substrate was made in this protocol. Practical application of this ocular estimate technique proved unreliable, and was demonstrated to be statistically unrepeatable. As a result, we abandoned this method beginning in the 1994 field season, and adopted a new random pebble count method, called Z-Walk (Bevenger, 1996), to quantify substrate types and

percentage of fines within the reach. Because this method of pebble count is usually performed after the physical habitat inventory, it is described in detail later in this document. Once collected, Z-Walk measurements can be grouped into the types of substrates we formerly quantified using the ocular estimate method. These groups of substrates are classified as the following (Bovee and Cochnauer, 1987) :

Bedrock (BRK), the rock which is considered parent material rock.

Boulders (BDR), the size of rock greater than 12 inches in diameter

Rubble (R), the size of rock greater than 3 inches to 11.9 inches in diameter

Gravel (G), the size of rock greater than 1/8 inches to 2.9 inches in diameter

Mud, Sand and Silts (S), the size of rock less than 1/8 inches in diameter

COMPLEMENTARY INVENTORIES

STREAM CLASSIFICATION

Stream Classification is used to categorize natural stream channels on the basis of measurable morphological features. This categorization thus allows for consistent and reproducible descriptions and interpretations, and can be readily obtained over a wide range of hydrophysiographic regimes (Rosgen, 1985). Stream Classification will be determined as described by Rosgen. Reaches within a stream will be classified by visual analysis (on-site), topographic maps and riparian maps. If obvious on-site stream classification changes are apparent within a reach, notes should be made on the field form and the location of the new channel type should be identified and marked on a topographic map.

WATER QUALITY AND BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate or bottom fauna communities can yield important information on water quality. Macroinvertebrates can provide estimates of the productive capacity of the stream and usually comprise a significant part of the diet of most trout. Individual species within a given community favor differing habitat conditions and vary in their tolerance to pollution and environmental stress. Thus, an analysis of the taxonomic composition and abundance of benthic macroinvertebrates found in our streams, can be very informative. Our sampling will consist of several taxonomic groups, such as Dipterans (Chironomidae - midges), Plecoptera (stoneflies), and Trichoptera (caddisflies). These groups are used on the basis of their predominance of the total benthic biomass and densities, both in numbers of species and individuals (Herrmann et al., 1986). Sampling of the benthic macroinvertebrates will be conducted with sweep nets, Suber and Hess samplers and Thienemann Net sampling (Thienemann, 1910), and identification will be conducted to the lowest taxonomic level possible. Additional calculations of diversity are made to develop a measure of the health of the macroinvertebrate community

Water quality testing should be based on the goals and objectives of the particular study. Common parameters measured include: pH, temperature, total alkalinity, total hardness, and conductivity. Water temperature is a measurement which should be collected at every inventory site. A maximum-minimum thermometer should be set in the stream (in a shaded area) the first thing in the morning, and retrieved at the end of the day. There is a space at the top of the field form for recording both the maximum and minimum stream temperatures. In stream reaches where potentially detrimental high temperatures or excessive diurnal temperature fluctuations are suspected limiting factors to fish propagation, long-term thermal monitoring should be considered. Temperature data loggers, such as the OpticStowaway loggers manufactured by ONSET Systems, Inc., can be placed in the stream for extended periods up to a year in length. These sensors should be placed within the thelweg portion of the stream, in such a manner that they will not be affected by direct sunlight. Benthic macroinvertebrate and water quality inventories and monitoring are incorporated into the analysis and monitoring phase based on the specific needs within each drainage.

VEGETATION

Riparian habitat and botanical identification will be noted in comments on the inventory sheet and in collections and photographs. These will be used to assist in the evaluation of the final inventory

analysis. A field guide to the Plant Associations of Region 2 is valuable in associating species found in the riparian (Johnston, 1987) The following species codes are used to describe, in descending order of abundance, the dominant riparian vegetation (Schmal et al., 1988) :

AL = Alder sp. (Alnus tenuifolia) **AS** = Aspen sp (Populus tremuloides)

CW = Cottonwood (Populus angustifolia, P. X. acuminata, P. fremontii wislizenii)

DF = Douglas Fir (Pseudotsuga menziesii) **ES** = Engelmann Spruce (Picea engelmannii)

FB = Forb sp **LP** = Lodgepole Pine (Pinus contorta latifolia)

RR = Rushes (Eleocharis spp , Juncus spp) **SF** = Subalpine Fir (Abies lasiocarpa)

Wi = Willow sp (Salix amygdaloides) **GS** = Grass sp (Poaceae)

PP = Ponderosa Pine (Pinus ponderosa)**SB** = Sagebrush sp (Artemisia spp)

SG = Sedge sp. (Carex spp) Other (specify)

PEBBLE COUNTS and Z-WALK

Pebble counts are used to analyze the size of material on the bed of a stream, based upon an analysis of the relative area covered by particles of a given size (Wolman, 1954). This analysis is also a way to determine the site composition of materials moving through the channel in each reach. Typical pebble count analysis is performed at predetermined habitat units along each reach. In these habitat units (representative glides, pools, and riffles) a grid system is established by pacing the stream channel. The size of the grid is determined by the length of reach which the sampler desires to describe. The substrate materials are sampled, measured, and recorded on the worksheet (Appendix V), and at least 100 samples are taken at each site. Samples are taken by walking along the transect (at some predetermined interval, i.e., every step or every other step) and picking up the first item touched by your finger at the tip of your leading boot. The material first touched is picked up and measured with a ruler (graduated in millimeters), across the intermediate axis of the sample. The other team member then records the measurement. A frequency distribution can be drawn from the sample, allowing percentage of fines to be calculated and the desired size parameters can be determined.

The greatest problem with this classic pebble count analysis is the inherent bias introduced in the selection of the 'representative' riffle, glide and pool habitats. Hydrologists have dedicated significant research into methods to eliminate this bias. One methodology in particular, the Z-Walk pebble count (Bevenger & King, 1995), appears to dramatically reduce the bias involved in selecting suitable pebble count sites, and has been demonstrated to be a statistically valid and repeatable technique for calculating substrate percentages along a given segment of stream. We have adopted a slightly modified version of this methodology for analysis of reach substrate within the BWSHI. A brief explanation of our use of this technique is described below.

Representative sites are not utilized in the Z-Walk method. Instead, the sampling team begins at the downstream boundary of the stream segment to be analyzed, and, sampling at a regular interval, work their way upstream in a zigzag diagonal direction. Sampling takes place not only within the wetted width of the channel, but also includes temporary dry areas up to the bank-full height of the channel. The specific methodology developed by Bevenger and King dictates a sample segment of stream that is 1,000 feet long. Within this segment, at least three hundred samples are made. Beginning at the downstream boundary, the sampler selects a random point 20 to 30 feet diagonally upstream on the opposite bank. Next, the sampler takes two paces in the direction of the selected random point, then

reaches down and selects and measures a single piece of substrate in the same manner as described above for a classic pebble count. The sampler then takes two more paces toward the random point, and samples another substrate. Once the sampler reaches the previously selected point on the bank, he repeats the process, selecting another point diagonally upstream on the opposite bank. This process is repeated until the end of the segment is reached. The most difficult part of this process is not watching (or selecting) where your boot falls when pacing up the stream. Care must be taken not to slip on large stones or step into deep pools. Because the stream reaches inventoried under the BWSHI protocol are almost always longer than 1,000 feet, we have slightly modified the Z-Walk technique for application in our inventories in order to eliminate the chance of bias being introduced by selecting a 1,000 foot representative segment. Under our use of this method, we will attempt to sample the entire length or significant portion of the reach. In order to reduce the time and labor required to collect this data, we expand the interval between samples from two to three or four paces, depending on the length of the reach. A sample set of at least three hundred observations is still considered desirable. While this may appear to be prohibitively labor intensive, the crew can perform this survey and collect a GPS line feature at the same time, eliminating multiple walks through the length of the reach.

DISCUSSION

In order to yield the best results, we feel that it is important to identify some potential pitfalls. As in any scientific study, repeatability and consistency of measurement are extremely important. Field teams must be properly trained to achieve adequate results, and potential problems are inherent in the protocol itself. Foremost, the inventory is best taken at seasonal low flows on the creeks or streams to be studied. This condition is necessary in order to have comparable data with which to compare previous or future inventories. These base flows, in smaller streams (i.e., 4th order or smaller) provide data on the minimum amount of habitat available, and often constitute an important limiting factor, in terms of habitat. This situation is generally not the same in our larger streams, which may be most limited by peak flow conditions. Winter low flows themselves can be limiting to fish populations. By inventorying habitat in seasonal low flows, these conditions can be evaluated for their importance as limiting factors.

Secondly, the measurements taken during the inventory must be consistent and repeatable for any future use in describing habitat. This is especially critical should restoration activities be conducted on the stream once limiting factors are discerned. If detailed maps of the locations and areas of all habitat unit types are constructed, then such maps can be used to compare habitat unit areas and sequences, between seasons or years. These maps can also be used to evaluate the effects of various habitat alterations (Hankin and Reeves, 1988). This concern is lessened by the use of a single two-man team performing the inventory. With the proper indoctrination and training, these crews can achieve a high consistency of measurement. The measurement error inherent in any study can be discussed and incorporated into the analysis of the results and can be appropriately dealt with, in the discussion of factors perceived to limit fish populations.

Thorough training of the survey crew cannot be stressed enough. Units that are just beginning to implement these surveys may be very frustrated initially, when novice crews are completing only a few hundred feet of surveyed stream in a day. We have found, however, that once crews are adequately trained, 1 to 1.5 miles of stream can be reasonably surveyed per day. One of the initial problems encountered when training new crews to perform these surveys is the tendency for different individuals to lump many small habitats into one, or split out micro-habitats from single HUTs. In order to maintain the consistency required for repeatable surveys, we have found that one survey crew, working Unit-wide, rather than several crews working in different areas, eliminates much of the problem inherent in the "Splitter vs Lumper" dilemma. Additionally, we have found it necessary to set a very specific criteria for splitting out habitats as a separate unit. This criteria requires that the habitat must be at least as long as the channel is wide. The only exception to this rule are plunge pools on a few small, very high gradient, boulder and bedrock streams, where plunge pools frequently encompass the entire stream channel but the pool length is relatively short.

The Office Procedures provide an excellent background overview of the stream and reaches to be inventoried by the field team. If all the information is obtained in completing Appendix I, then the field crew should have a good feel for the conditions in the stream and reaches to be inventoried.

Reach delineation and boundaries are critical for consistency, accuracy, and repeatability in the BWSHI. Reaches should be hydrologically and geomorphologically consistent. Significant changes in channel slope and geometry, total stream discharge, and watershed aspect should be considered when delineating reaches. Your data will be severely compromised and skewed if you combine habitats from one segment of stream flowing at 40 cfs with another set of habitats in a segment of stream flowing at 20 cfs into a single reach. Additionally, reach boundaries must be easily re-locatable. We have found that confluences with tributaries are the most effective reach boundaries. In situations where a tributary or other permanent feature cannot be found, GPS or other repeatable method of locating the reach boundary must be used.

When measuring HUT's, careful attention must be given to designation of endpoints. Consistency in choosing these points is critical for the variance inherent in these metrics to be as low as possible. Use of a metal pin with a piece of fluorescent tape tied to it, placed by the measurer, is one method to insure the recorder knows exactly where one HUT ends and the other begins. At an absolute minimum, the person leading with the tape should remain at the endpoint location until the recorder arrives at the endpoint location. The tape holder can then point out the precise spot where the endpoint was placed.

Horizontal geometry and shape of the Habitat Unit should be considered when performing length and width measurements in order to accurately assess the total wetted area of the HUT. A certain amount of common sense is required here. The methodology states specific methods to maintain random selection of width measurement cross-sections. However, some discretion should be used in certain odd or irregular shaped habitats. Remember that the goal is to portray an accurate assessment of habitat dimensions and area.

Another problem encountered in the field is the determination of which channel, in a split or secondary channel condition, should be measured as the main channel. A rule of thumb, is to select the channel containing the largest flow of water as the main channel. However, if both channels appear to have the same amount of water flowing through them, then one of two alternatives will need to be considered. In this situation the crew will need to walk both channels to determine if the habitats in each are homogeneous. If habitat within each channel is identical, the lengths of the channels are similar, and the length of the channels are not greater than five times the width of the average channel throughout the reach, then we consider the landform separating the channels as an island. In this case, we measure each channel width, and add them together, effectively combining the two channels into one habitat unit. If the two channels appear to have similar flow but exhibit different habitat types, or do not meet the other criteria in the alternative above, then we select the right channel as the main and measure the left channel as the secondary.

It is important to note at this time, that we separate out the side channels and side pools in our analysis of the reach. We treat these HUT's independent of the main channel HUT's, especially in determining lengths and surface area and volume measurements for the reach. These HUTs are very important in providing habitat to various life stages of fishes and as such are analyzed independently, especially in low flow regimes. We separate these habitat types because we are interested in a statistically valid

analysis of our inventory. We do not want to overestimate these values, which would be the case if they were included as main channel habitat unit types. This is in keeping with what Hankin and Reeves (1988) discussed in terms of the differences between "representative reach" inventories which tend to overestimate the available habitat and the "statistically valid-observational" inventories, which this protocol describes.

Included in any inventory study, are recommended items of equipment necessary to complete the assignment (Appendix V). We have also listed in Appendix VI estimated costs associated to perform this inventory in 1997.

We feel that this inventory, when coordinated with other resource inventories, provides a quantitative and repeatable analysis of stream and habitat conditions. By conducting the basinwide inventory as described, the information collected can be a valuable tool for decision makers, concerning the health of our aquatic and terrestrial ecosystems.

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APPENDIX I

GENERAL REACH HABITAT PRE-INVENTORY FORM

Date(s):_____ Upstream_____Downstream_____

1. Stream Name:_____

2. State:_____ 3. Forest:_____ 4. District:_____

5. USGS Map:_____

6. Catalog No.:_____

7. Reach Legal Location: T_____R_____Sec_____Qtr_____

GPS Downstream (UTM) - N_____E_____

GPS Upstream (UTM) - N_____E_____

GPS File Name:_____

8. Reach No.:_____of_____ 9. Upper Reach Elevation_____ft.

Lower Reach Elevation_____ft.

10. Reach Gradient:_____

11. Photograph Exposure No: Roll No.:_from_____through_____

12. Dominant Riparian Vegetation:_____

_____

_____

13. Riparian Zone Width:_____ft.

14. Valley Bottom Width:_____ft.

15. Valley Bottom Shape:_____

16. Discharge:_____cfs 17. Mean Velocity:_____ft/sec

18. Current Meter:_____

19. Channel Type and Subtype:_____

20. Fish Species and Densities:_____

21. Bank Full Width and Depth:_____

22. Comments:_____

_____

_____

_____

23. Investigators:_____

APPENDIX II

BASIN-WIDE STREAM HABITAT INVENTORY FIELD FORMS

APPENDIX III
BASIN-WIDE STREAM HABITAT INVENTORY HELP SHEET

1 Number, either **GLIDE= G** (1,2,3...) **POOL= P** (1,2,3...) **RIFFLE= R** (1,2,3...)

2. TYPE: **GLIDE= 1**

POOL=	**RIFFLE=**
2. secondary channel	8. secondary channel
3. backwater	9. bedrock
4. trench	10. boulder
5. plunge	11. cobble
6. lateral scour	12. gravel
7. dam pool	13. sand/silt
	14. rapid
	15. cascade

3 STRUCTURAL ASSOCIATION

A - bar
B - boulder
C - culvert
D - beaver dam
E - bedrock
F - falls
L - LOD (4"dia.-3ft long)
M - stream meander
0 - other, (low gradient riffles)
P - pocket water (riffles w/high gradients)
R - rootwad
S - man-made structure
W - debris dam/large wood

4 LENGTH **5 WIDTH** **6 RESIDUAL POOL DEPTH** (High-Low = RPD)

7 AVERAGE DEPTH (Pools Only) **7a MAXIMUM DEPTH** (Pools Only)

8 COVER TYPES - measure and record in square feet of cover as visually determined:

1 - **No cover** - depth <0.5 ft, velocity ~0.5~/sec in riffle; pools <1.~ ft deep **No Securlty Covcr**.
2 - **Instream cover** - water level 1ft deep behind objects 1 ft in width, reducing velocities to < 0.5cfs, LOD (tree trunks, root wads), boulders.
3 - **Overhead cover** - within 2ft of water surface, vegetation like shrubs above glide or pool, undercut banks, protruding banks providing a minimum of 1 ft of cover, H_20 min. 0.5ft depth, velocity<0.5 cfs, and offers **NO Velocity Shelter**.
4 - **Combination cover** - water>0.5ft, passing over fallen trees, debris dams w/branches and/or root masses, overhanging banks with roots, rubble or boulder piles within the stream channel; provides reduced water velocities and overhead cover.
5 - **Pool Depth cover** - plunge pools over debris jam, lateral scour pools in undercut banks, any area of pooling >1.5ft deep after codes #2, 3,& 4 above have been measured; the remainder is then measured as pool depth cover.

9 BANK STABILITY

1 - Vegetated and Stable,	>50% vegetated, bank does not show stress
2 - Vegetated and Unstable	>50% vegetated, bank does show stress
3 - Unvegetated and Stable	<50% vegetated, bank does not show stress
4 - Unvegetated and Unstable	<50% vegetated, bank does show stress

10 BANK ROCK CONTENT

2 - >65%	consisting of large angular boulders, 12" diameter
4 - 40 - 65%	consisting of small boulders to cobbles, 6-12" diameter
6 - 20 - 40%	with most consisting of rocks in the 3" diameter class
8-<20%	consisting primarily of rock fragments of gravel size, 1/8-3" diameter or less

11 ERODING BANKS - measure the amounts in linear feet of erosion on each bank and record the sum.

12. LOD - large organic debris, diameter > 4" and length >3.3', record the total number of objects.

13 SUBSTRATE TYPES

BDR boulders, assess within 5 ~o of the % of the streambed covered by size	>12"dia
R rubble	>3-11.9"dia.
G Gravel	> 1/8-2.9"dia.
S mud,sand/silt	<l/8"dia.
BRK bedrock	parent material
PD plant debris	aquatic vegetation

APPENDIX IV: JOB HAZARD ANALYSIS AND SAFETY

Safety of all personnel working on these inventories should be the primary concern of supervisors, crew leaders and workers alike. Stream ecosystems can become extremely dangerous work environments if care is not taken by all parties involved. In 1993, we undertook a job hazard analysis of the BWSHI inventory and related aquatic data collection activities in order to identify and minimize the potential risks and hazards our workforce may be exposed to in the coarse of this work. The following guidelines summarize the results of this job hazard analysis (Gallagher & Winters, 1993).

SMALL STREAM HAZARDS

Slippery and/or unstable footing: Falls represent the greatest hazard faced when inventorying small streams. Adequate hip-boots with felt soles in good condition must be provided for all individuals working within cobble and larger substrate streams. Avoid stepping on large organic debris. Feet should be kept spread apart to aid balance, and only small steps should be taken.

Hunters During the Fall hunting seasons, all workers should wear International Orange work vests or hats.

LARGE STREAM HAZARDS

In addition to the hazards outlined above, large streams and rivers also present hazards related to higher flows, swift currents, and deep pools. Do not wade if velocity in ft. per sec multiplied by depth exceeds a value of 10 or more. All workers should be competent swimmers. All workers must use properly fitting chest high NEOPRENE waders with felt soled boots. In addition workers must use a wading belt to prevent accidental filling and loss of buoyancy. Under NO circumstances should workers performing BWSHI ever tie themselves into any fixed object with a rope or cable. BWSHI should always be performed at mean low flow. If the current is too swift, you should probably not be performing the inventories at that time.

WEATHER AND OTHER ENVIRONMENTAL HAZARDS

Hypothermia: All workers should have one spare change of clothes kept in the FS vehicle whenever performing aquatic inventories. Hypothermia becomes a real possibility as a result of a fall into a stream. If working more than 1/2 mile from the vehicle, spare clothing should be carried in a pack and left near-by the work area. In addition, adequate rain gear should be carried by all workers.

Dehydration: Adequate fresh water supplies should be carried by the crew, particularly on warm summer days at high elevations. Never drink water directly from the stream unless it has been treated or filtered against Giardia and other water-borne pathogens.

Sunburn: The degree of severity of sunburn is intensified when working on water, and liberal use of sun screens are required.

Lightning: In the event of approaching thunderstorm all work in the stream must be suspended, and all workers must leave the water until the storm has passed. Identify and use protected areas during storms

FLORA

Hazards include poison ivy, briars, and being speared by willows. Workers should be able to identify poison ivy and avoid it. When working on small streams and areas of dense riparian vegetation, long-sleeve shirts should be worn, and eye protection should be provided.

FAUNA

Make a lot of noise when walking to and from the study site. Poisonous snakes are generally not encountered, except on approaches to and from the site. In case of poisonous snake bite, DO NOT try to open the wound and suck out the poison! Seek immediate medical attention. Spiders, including some poisonous varieties, may be encountered within the study area, and can be avoided by clearing away webs. During tick season, insect repellent (100% DEET) should be used, and clothing should fit snugly around ankles, wrists, and collar. Check the body frequently during tick season. Workers should notify co-workers and supervisor if they have known allergic reactions to insect or bee stings. Workers should be aware of bears and other large animals and predators inhabiting the stream ecosystem and give them a wide berth. Beavers present a unique problem; not only do their dams present hazards from slipping and being speared by 'Beaver Bungi Sticks', but being rodents, they can also be carriers of rabies, plague, and hantavirus. Avoid contact with these and all other rodents.

ELECTRO-SHOCKING HAZARDS

Section 3-27 of the FS H&S Code Handbook is specific about precautions that must be taken when electro-fishing. Chest high waders in good condition and elbow length rubber electrician's gloves (ANSI J6.6-1967) must be worn. All equipment must have both automatic and manual circuit breakers. Never have backpack operators responsible for capturing fish unless one of the electrodes is in a net. Never operate an electro-fishing device with less than a two man crew, and locate at least one crew member near the unit to break the circuit in emergencies. All movement should be slow and deliberate.

GENERAL HAZARDS & SAFETY

The best method of accident prevention is to use common sense and good judgment. Learn to recognize hazardous situations and avoid them. Realize that hazards can occur not within the stream, but also on the approach and departure. Avoid situations where fatigue or workload pressure results in a lapse of judgment. Preferably, all workers should be trained in basic First-Aid and CPR. At a bare minimum, at least one crew member should be certified in these skills.

APPENDIX V

EQUIPMENT LIST FOR PERFORMING BWSHI

PRIMARY ITEMS		*SECONDARY ITEMS*
_____ HIP WADERS (2 PAIRS)	*OR*	_____ NEOPRENE CHEST WADERS & WADING BOOTS (2 PAIRS EACH)
_____ 16 FOOT SURVEY ROD (ORANGE CASE)	*AND / OR*	_____ 25 FOOT SURVEY ROD (TAN CASE)
_____ 200 FT METAL MESURING TAPE	*AND / OR*	_____ 100 FOOT NYLON TAPE (ORANGE TAPE)
_____ 0 TO 250 FOOT RANGEFINDER		
_____ 250 TO 1000 FOOT RANGEFINDER		
_____ 30 FOOT STANLEY TAPE		
_____ MIN / MAX THERMOMETER		
_____ MARSH-MCBURNEY FLOW METER	*AND*	_____ VISE-GRIP TAPE CLAMPS
_____ TOP-SET WADING ROD		
_____ TWO-WAY RADIOS (WITH EXTRA BATTERIES)		
_____ CAMERA BAG w\ EXTRA FILM		
_____ BASINWIDE FORMS (BASFORM5.XLS)		
_____ COPY OF PROTOCAL CHEAT SHEET		
_____ PENCILS / MARKING PENS		
_____ CLIPBOARD		
_____ CALCULATOR		
_____ INCLINOMETER		
_____ ORANGE VESTS		
_____ WOODEN STAKES (1 DOZEN)		
_____ IRON STAKES (RE-BAR)		
_____ SURVEY TAPE (ORANGE)		

APPENDIX VI

EXAMPLE OF COSTS OF PERFORMING BWSHI AND RELATED INVENTORIES IN FY1997

Cost of Personnel

$ 249.00/Day	GS-12 PFT Aquatic Biologist
$ 124.00/Day	GS-7 Term Aquatic Tech
$ 85.00/Day	GS-5 NTE Seasonal Biological Aid

Basin Wide Stream Habitat Inventories **(Three miles on three Creeks)**

Thirty-one Mile Creek
Agate Creek
Rye Slough

$ 744.00	6 Days - AquaticTech
$ 510.00	6 Days - Bio Aid
$ 498.00	2 Days - Aquatic Biologist

$ 1,752.00	Total Personnel Costs - Basin Wide Stream Surveys
$ 584.00 per mile	Cost per mile of stream Inventoried.

Temperature Studies Six streams

Rye Slough
Thirty-one Mile Creek
Agate Creek
Sheep Gulch
Three Mile Creek Exclosure
Three Mile Creek downstream from Exclosure

$ 372.00	3 Days - Technician prepare and set sensors
$ 249.00	1 Day - Aquatic Biologist support
$ 248.00	2 Days - Technician retrieves sensors
$ 100.00	Misc. Materials to anchor sensors
$ 750.00	Six ONSET Systems OPTIC-STOWAWAY 8k temperature data loggers

$ 1,719.00	**Total Personnel and Materials - Water temperature Monitoring**
$ 286.50	**Cost per stream to temperature monitor (approx. 1 mile of stream monitored at each site)**

APPENDIX IV *Continued*

Report Preparation

$ 1,240.00	10 Days Draft and Final Report Prep - Aquatic Tech.
$ 425.00	5 Days Data Entry - Biological Aid
$ 1,245.00	5 Days Report Prep and Review - Aquatic Biologist
$ 2,910.00	Total Personnel - Report Prep.
$ 6,381.00	Total Cost - Aquatic Monitoring for RAMP Revision
$ 709.00	Cost per mile for 3 miles of stream inventoried and 6 miles of stream temperature monitored.

Total Days

8 Days	Aquatic Biologist
21 Days	Aquatic Technician
11 Days	Biological Aid